unable to effectively care for self or fellow diver in case of an emergency. Must dive with two certified divers, one of whom has been trained in diver rescue.

Safety precautions with special significance to disabled divers include the conservative use of dive tables to avoid decompression sickness, caution to avoid abrasions and puncture wounds on insensate extremities, and protection against sunburn or chilling by wearing suitable clothing.

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Electrodiagnosis in Bladder, Bowel, and Sexual Dysfunction

BLADDER, BOWEL, AND SEXUAL DISORDERS are common symptoms of peripheral and autonomic neuropathies, sacral and peripheral nerve injuries, and diseases that affect the brain and spinal cord. New electrophysiologic techniques permit the precise localization and quantification of disturbances in neuromuscular innervation of the bladder, the bowel, and the sex organs. Sacral electrodiagnosis is of clinical importance in the evaluation and subsequent rehabilitation of patients with cervical and lumbar disk disease; pelvic fractures and tumors; arachnoiditis; peripheral neuropathy; spinal cord injury; transverse myelitis; spinal cord tumor; multiple sclerosis; and neurogenic bladder, bowel, and sexual dysfunction.

Electromyography of the perineal sphincters is well established as an important tool in the study of urinary and fecal incontinence and retention. By means of a needle electrode placed directly into the anal or urethral sphincter, signs of acute and chronic degeneration can be found in the striated muscles innervated by the lower sacral segments. Another way to analyze electromyographic activity is to record electrophysiologic patterns by summation and electronic integration. When done with surface or needle electrodes in conjunction with urodynamic studies, detrusor-sphincter dyssynergia can be documented.

The integrity of sacral spinal cord segments S-2, -3, and -4 has classically been evaluated by manually stimulating the glans penis or glans clitoris and observing or palpating contraction of the external anal sphincter. The evaluation of the sacral reflex has recently been refined to the point where sacral cord neural integrity can be recorded and objectively quantified. The bulbocavernosus reflex is evoked electrically by providing an electrical stimulus to the pudendal nerve of the penis or clitoris and recording from the bulbocavernosus muscle, the external anal sphincter, or the external urethral sphincter. The resultant reflex electromyographic deflection, which usually occurs up to 45 ms after stimulation, is an indicator of the integrity of the peripheral somatic sensory and motor pudendal pathways as well as conduction through the sacral spinal cord. Other indicators of sacral neuropathy include a diminished amplitude of the evoked response (less than 50 to 200 μV) and the need for a higher-than-usual stimulus intensity. When the latency of the reflex is more than 7 ms slower on one side than the other, a unilateral lesion is probable, as with a herniated nucleus pulposus. In patients with severe conus medullaris or cauda equina lesions the reflex cannot be elicited at all.

Abnormalities of the autonomic nervous system are often responsible for bladder, bowel, and sexual dysfunction. Applying an electrical stimulus to the proximal portion of the urethra stimulates the afferent autonomic innervation through the hypogastric nerves. The evoked efferent response from the anal sphincter usually occurs within 70 ms after stimulation. This technique significantly enhances the accuracy of the diagnosis of autonomic neuropathies.

Recent applications of digital computer microelectronic averagers have opened the way to spinal and cortical evoked response testing. Somatosensory evoked responses subsequent to pudendal nerve stimulation may be recorded over the L-1 spine at the level of the conus medullaris and over the scalp in the region of the sensory cortex. Spinal evoked responses are of low amplitude—0.1 to 0.5 μV—and difficult to elicit if a patient is obese or if there is even a mild peripheral neuropathy. The cortical evoked response, however, may be consistently recorded electroencephalographically from an electrode placed in the midline of the scalp 2 cm behind the C-2 recording site using the international 10 to 20 electrode placement protocol. The averaging of 256 to 1,024 responses results in a well-formed reproducible response—amplitude 0.5 to 2 μV in male subjects and 0.2 to 1 μV in female subjects. The latencies of onset are similar to those obtained when the posterior tibial nerve at the ankle is stimulated—up to 45 ms.

These electrophysiologic techniques permit a precise assessment of the sensory and motor nerves of the sacral reflex arc and examination of the sacral nerve roots, cauda equina, conus medullaris, and the central nervous systems from sacral cord to sensory cortex. An accurate diagnosis is prerequisite to applying specific rehabilitative methods to treat bladder, bowel, and sexual dysfunctions.

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Robotics for Rehabilitation

COMPUTER-BASED, VOICE-CONTROLLED ROBOTS can enhance the quality of life for a person with high-level quadriplegia, particularly with an injury above the level of C-5 to C-6. Using robots can provide greater control over a person's physical environment, expand avocational and vocational horizons, reduce the expense of attendant care, and improve self-esteem.

Rehabilitation robotics began evolving in the early 1960s with Case Institute of Technology's (Cleveland) computerized orthoses. In the early 1970s, the University of Heidelberg developed an industrial manipulator and minicomputer through which a keyboard controlled by a telephone, typewriter, or a custom mouth-stick could be used for vocational purposes by handicapped persons. In 1981 the Johns Hopkins University's applied physics laboratory designed a more advanced robotic system permitting preprogrammed manip-

ulation sequences for tasks such as retrieving books and serving food. The French Spartacus robotic aid made other contributions to the evolution of the field of robotics.

During the past eight years, the Stanford University and the Veterans Administration Rehabilitation Engineering and Research Center, in collaboration with the Spinal Cord Injury Center (all in Palo Alto, California), have explored through a number of projects the potential use of robots as assisting devices for severely disabled persons. A wide range of users successfully commanded a robot to perform preprogrammed self-care tasks such as providing drinking water, grooming the hair, brushing teeth, and cleaning the face. A third-generation desktop robotic assistant has already been developed and clinically evaluated for persons with high-level quadriplegia. Advances in speech-recognition technology and commercial computer hardware and software have significantly augmented the uses of the system PUMA-260 robot manipulator. Efforts are currently being directed to develop a desktop system that would be useful for a skilled computer scientist in an office setting. The most recent developments in progress include a controlled mobile manipulator consisting of a commercial robotic arm equipped with sensors and mounted on an omnidirectional vehicle, useful to a handicapped person confined to a bed or wheelchair.

Ordinarily no knowledge of computer programming is required to operate the robotic arm; the on-board microprocessor is preprogrammed by a therapist to perform complex tasks in response to one or two commands from the user.

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Prophylaxis and Control of Seizures in Brain-Injured Patients

POSTTRAUMATIC SEIZURES are estimated to occur in approximately 5% of all patients with head injuries and anywhere from 20% to 60% of those with penetrating head injuries. The issue of seizure prophylaxis or treatment following a brain injury often arises in the early days after the injury. Treatment is often instituted with either intravenous phenytoin or phenobarbital in the neurosurgical unit, with conversion to the oral form when the patient is transferred to the rehabilitation service.

Investigators have recently been evaluating the cognitive effects of the use of phenytoin, phenobarbital, or carbamazepine on both persons newly diagnosed with epilepsy and those known to have epilepsy. These studies have important implications for the head-injured population because a disordered cognitive state already exists and further disruption may impede the rehabilitative effort. A comparative study showed little difference in the efficacy of these drugs in controlling tonic-clonic seizures.

In newly referred patients with epilepsy, the use of carbamazepine is associated with a better performance on memory tasks compared with that of phenytoin. Although no significant difference was found on mood ratings between the two drugs, higher blood concentrations of carbamazepine yielded lower ratings for anxiety, depression, and fatigue.

In epileptic patients whose regimen is changed from other anticonvulsants to carbamazepine, tests of memory and concentration show significant improvement. Improved cognitive functioning has also been shown when the number of drugs is reduced without an adverse effect on seizure control.

Although no anticonvulsant study has specifically examined cognitive effects on patients with brain injuries, based on the available data, it seems appropriate to recommend using carbamazepine as the first-line agent in this patient population. Phenytoin is an appropriate alternative if carbamazepine use is not tolerated. Phenobarbital is the least appropriate drug because of its sedative and cognitive effects.

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Advances in Surgical Reconstruction of Upper Extremities in Quadriplegia

THERE IS INCREASING INTEREST in and awareness of the role of surgical reconstruction for paralyzed upper limbs of patients with quadriplegia. A greater number of Veterans Administration and other public and private spinal cord injury centers are offering the possibility of surgical reconstruction to their quadriplegic patients, and an increasing number of patients are undergoing reconstruction in the hope of gaining more independence.

In the past decade novel operative techniques have been developed that extend the possibility of reconstruction to patients with more proximal cervical cord lesions. A useful international classification system has been developed that categorizes patients not on the spinal level of injury but by their remaining functioning upper extremity muscles. As spinal cord injury centers have gained experience with sufficient numbers of patients who have had such operations, ideas about the role and timing of upper extremity reconstruction in the overall rehabilitative process have taken form.

We recently reviewed our ten-year experience at two centers, the spinal cord injury services at the Palo Alto (California) Veterans Administration Medical Center and at Denver's Craig Rehabilitation Institute. During this period more than 400 patients with quadriplegia were examined and more than 170 patients underwent some type of surgical reconstruction for their upper extremity carried out in almost 250 operative procedures. For those patients whose only remaining function was active wrist extension, a one-stage key pinch between thumb and index finger was done (72 limbs). For those patients with a greater number of remaining functional forearm muscles (67 limbs), a two-stage procedure provided both active digital grasp and release and a strong thumb pinch. Active release was accomplished in the first stage and grasp and pinch provided in the second stage. In 40